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What is the impact of research funding on research productivity?
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Project title: What is the impact of research funding on research productivity?

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AIM

1. To evaluate the impact of receiving funding on researcher productivity

SIGNIFICANCE

How much research funding improves research productivity is a question that has relevance for all funding agencies and governments around the world. Previous studies have used observational data that compares productivity between winners of different amounts of funding, but researchers who win lots of funding are usually very different from those who win little or no funding. This difference creates potentially serious confounding which biases any estimate of the effect of funding based on observational data that simply compares research output for those who did and did not win funding. This means we do not currently know the return on investment for our research dollars, of which billions are invested around the world every year.

By using a study design that incorporates randomisation this will be the world's first unbiased study of the impact of researcher funding.

HYPOTHESIS

1. Winning research funding will have no impact on productivity.

As is traditional we have used the null hypothesis, but have strong prior expectations that there will be an improvement in productivity. Nevertheless we still need to test this hypothesis and in doing so we will also estimate the size of any improvement.

Background

We will answer the question using a randomised controlled trial. The New Zealand Health Research Council has been using randomisation to assign funding to equally qualified applicants for the past two years. Randomisation is a low-cost, fair and transparent approach for choosing between equally qualified applicants. Examples of its current use include allocating places on over-subscribed medical degrees and for over-subscribed US visa applications [1].

Random allocation for medical research funding has been discussed in the literature, with the cited advantages cited that it avoids peer review biases and has a small administrative burden, and the disadvantage that it will not capture all deserving scientists [2]. However, given the low levels of funding for many schemes around the world, it is widely acknowledged that many deserving scientists are currently not funded. A 2013 review of alternative models of funding allocation by the Rand corporation found that random allocation had not then been applied to large scale funding [3]. This review also pointed out the small administrative burden for funders, the potential avoidance of biases, and the transparency of using random allocation.

Our previous study of National Health and Medical Research Council (NHMRC) Project Grants provides support for using random allocation to award funding as we found that 29% of applications were in a "grey zone" where they were sometimes funded and sometimes not depending on the make-up of the panel [4]. We also know that randomness can influence funding decisions via random events such as the spokesperson assigned to an application and the day of the week the application was reviewed on (NHMRC peer review panels meet for a week).

Related studies

A US study found a modest 7 percent increase in publication numbers when comparing funded and non-funded applicants to the NIH [5]. A study in Argentina compared grant winners with losers and found a significant positive effect of funding, especially for younger researchers [6]. However, in both these studies the awarded of funding was not done at random, meaning that the estimated effects are potentially biased, and the Jacob & Lefgren study recommended that a randomised trial be used to identify the causal effect.

In the grey literature, academics have talked about the potential benefits of a lottery system in newspaper articles [7], blogs [8, 9] and letters [10, 11]. There has also been an editorial from the NHMRC CEO that specifically criticised lotteries [12].

There are few previous studies in the area of research funding. A 2007 Cochrane review concluded, "There is little empirical evidence on the effects of grant giving peer review", and that, "Experimental studies assessing the effects of grant giving peer review on importance, relevance, usefulness, soundness of methods, soundness of ethics, completeness and accuracy of funded research are urgently needed" [13].

A previous study investigated the impact of larger versus smaller grants on productivity [14]. It used four measures of researcher productivity over four years post-funding: numbers of articles published, numbers of citations to those articles, the most cited article, and the number of highly cited articles. It found a diminishing returns in productivity with higher amounts of funding, suggesting that more smaller grants is a better approach than fewer larger grants. A similar study in the US found no association between peer reviewers' scores and the citations of funded project [15]. The expectation would be that projects with a higher score would have done better because they were judged as better by peer reviewers. A smaller study of just 41 funded projects also found no association between peer reviewers' scores and productivity [16]. This study examined three measures of productivity: the number of publications, the mean number of citations per year of those publications, and the number of citations of the most frequently cited publication. In contrast a moderate association between peer reviewer scores and productivity was found by a recent study of funding awarded by the American Institute of Biological Sciences [17]. This study used total citations as the main outcome.

These studies are useful for our purposes as they demonstrate:

- Some support for using randomisation among equally qualified applications, as peer review has often failed to be predictive of productivity
- The metrics that are used to define research productivity (paper and citation numbers)
- That previous studies have been on the impacts of project funding, not people funding. Importantly all the previous studies have compared results within funded projects. No other study has compared those who were funded and not funded.

New Zealand Health Research Council

The New Zealand Health Research Council has been using random allocation to award funding for its Explorer Grants [18]. Explorer Grants aim to provide seed support for transformative research ideas at an early stage. Up to four Explorer Grants per year are available in any health research discipline and are worth $150,000 NZD for up to two years. The following quote from the guidelines [18] summarises the scheme's aims:

> The proposal must advance ideas considered to be transformative, innovative, exploratory or unconventional, and have potential for major impact. An impact on knowledge is valid, and the idea need not be immediately applicable in terms of a health outcome. Assessment will focus on the research idea and the identity of applicants will not be disclosed to the assessing committee.

The following quote from the guidelines [18] summarises the selection process:

> All proposals that meet the eligibility criteria will be assessed for compatibility with the scheme's intent; proposals will not be scored or ranked. All proposals that are considered eligible and compatible will be considered equally eligible to receive funding, and a random process will be used to select the proposals to be offered funding.

Our study will take advantage of the existing randomisation used by the New Zealand Health Research Council to allocate funding to create a randomised controlled trial.

METHODS

This will be a randomised controlled trial of the impact of funding on researcher productivity.

Consent

The New Zealand Health Research Council will integrate our study into their current grant procedures. They will approach all short-listed candidates on our behalf to ask them if they would be willing to participate. The researchers will be asked whether they want to participate in a research study should they fail to win funding. We do not need to recruit the successful applicants as their names will be published on-line and hence there is no need to gain their consent.

The New Zealand Health Research Council will send us the names and institutions of the consenting researchers. We will need the institution to avoid any confusion for a researcher with a common name. We will follow the public announcement of the grant winners to assign the researchers to the successful or unsuccessful group. We will use the researchers for the 2015, 2016 and 2017 rounds, giving us 12 researchers in the case group and approximately 24 in the control group.

Inclusion and exclusion criteria

Inclusion criterion:

- New Zealand researchers short-listed for the Explorer Grant scheme in 2015, 2016 or 2017

Exclusion criterion:

- Researchers who refuse to consent and do not receive funding

Outcomes and databases

Our primary outcome will be the number of published papers per researcher. The number of papers is a widely used indicator of researcher output.

Our four secondary outcomes will be:

- Average impact factor
- Total citation numbers
- Other research funding (dollars)
- The number of other Health Research Council funding applications

The first two secondary outcomes are designed to measure an improvement in quality that may be independent of the number of papers. The third secondary outcome is designed to measure a researcher's success in winning other funding. The fourth secondary outcome is designed to measure increased productivity, as one potential benefit of winning funding is having more time to apply for further grants. All outcomes will be measured at the researcher level.

The number of published papers, impact factor and citation numbers will be extracted from the Scopus database using the author search facility. Other research funding will be extracted from the researchers' CVs (publicly available) and from public databases or announcements of New Zealand grant agencies. Researchers will not be directly approached for any information after they have given their consent to participate. This is a deliberate choice in order to reduce the burden on researchers of participating in the study.

The Scopus data will be extracted in 2020 to give 3 to 5 years of follow-up on each researcher.

Sample size

We anticipate 12 researchers in the awarded group and 24 in the not awarded group. These numbers are based on their being 4 awards per year and recruiting for three years (2015 to 2017). We expect double the number of unsuccessful researchers. These numbers give us an 91.4% power to detect a doubling in the rate of published papers for those researchers awarded funding. This power was estimated using a linear mixed effects model assuming a linear increase in paper numbers over time and a random intercept for each researcher. We used Scopus data from the three published winners in 2014 [19] to estimate the likely ranges in the yearly numbers of papers. We assumed that researchers who were not funded would continue at the same rate of increase, whereas those who were funded would double their rate of increase starting in the year after they were awarded the grant.

The Scopus data on the number of papers per researcher per year for three three winners from 2014 are shown in Figure 1. It is clear that the researchers' output is increasing over time. This is as expected as researchers become more experienced over time and more involved in a greater number of projects. The average increase in papers is 0.20 per year (95% confidence interval 0.12 to 0.29). In other words, output increases by an extra 1 paper per year every 5 years (1/0.20). We will account for this expected increase and see whether there is a change in the rate of increase after funding.

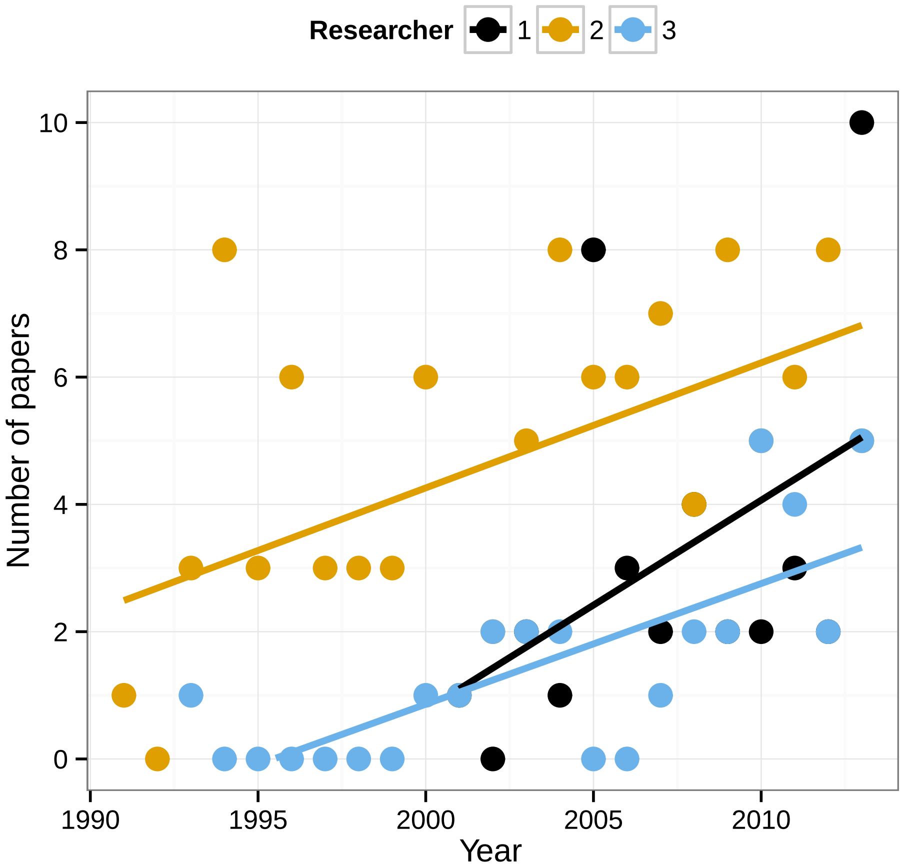

Figure 1: Number of papers over time up to the year prior to the award (2013) for the three winners of the HRC Explorer Grants in 2014. The dots show the observed number of papers from Scopus and the lines show a linear regression per researcher based on time.

Statistical methods

We will use a mixed effects regression model to examine a change in the number of papers [20]. The model is shown as an equation below:

$$
\begin{aligned}
p_{i,t} &\sim \text{Normal}(\mu_{i,t}, \sigma^2), \qquad i = 1, \ldots, m,\ t = s_i, \ldots, n, \\
\mu_{i,t} &= \alpha_0 + \alpha_1 Y_t + \alpha_2 c_{i,t} + \beta_i, \\
\beta_i &\sim \text{Normal}(0, \sigma^2_\beta).
\end{aligned}
$$

The mean number of papers for researcher i in year t are assumed to follow a normal distribution. The regression equation contains an intercept, a linear term for time (as shown in Figure 1) and the effect of funding which is explained below. The random intercept per researcher models the constant difference in output between researchers that we are not interested in. The start year for each researcher (s_i) is dependent on when they first published a paper (as shown in Figure 1).

The key parameter to describe funding over time is:

$$c_{i,t} = \begin{cases} t - a_i, & \text{if}\, w_i = 1 \;\text{ and }\; t > a_i \\ 0, & \text{otherwise} \end{cases}$$

where w_i is a binary variable that is 1 for successful researchers and 0 for unsuccessful researchers, and a_i is the year of the award for researcher i. Hence we expect a linear divergence in output starting the year after the award.

The impact of funding on the secondary outcomes will be estimated using the same model, although we may need to log-transform the data if there is a strong positive skew as there is likely to be for the dollar amount of other research funding.

A recent paper discussed the need to adjust for baseline when estimating differences in follow-up data [21]. It confirmed that a randomised trial will be unbiased whether baseline is adjusted for or not, but that adjusting for baseline should reduce the standard error of the effect of the randomised treatment ($\hat{\alpha}_2$ in the equation above) and hence increase the study's power.

All results will be presented in aggregate form (e.g., group averages) making it impossible to identify individual researchers. The names or institutions of individual researchers will not be shown any published papers or presentations. The data will not be shared with other researchers for further analysis.

Analysis by consent

The primary analysis will use all consenting researchers. As a sensitivity analysis we will also run an analysis including researchers who did not consent but were awarded funding. As they were awarded funding their data is in the public arena and consent is not required. However, there may be differences between researchers who choose to consent or not. For example, those who consent may be more confident because they have a stronger track record. This could potentially introduce a bias by creating a positive difference in experience between the case and control groups.

This sensitivity analysis will not be needed if the consent rate is high.

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